TECHNICAL REPORT

Contract Title:	Infrared Algorithm Development for Ocean Observations with EOS/MODIS
Contract:	NAS5-31361
Type of Report:	Semi-annual
Time Period:	January-June 1995

Principal Investigator:	Otis B. Brown RSMAS/MPO University of Miami 4600 Rickenbacker Causeway Miami, Florida 33149-1098

INFRARED ALGORITHM DEVELOPMENT FOR OCEAN OBSERVATIONS WITH EOS/MODIS

Abstract

Efforts continue under this contract to develop algorithms for the computation of sea surface temperature (SST) from MODIS infrared retrievals. This effort includes radiative transfer modeling, comparison of *in situ* and satellite observations, development and evaluation of processing and networking methodologies for algorithm computation and data accession, evaluation of surface validation approaches for IR radiances, and participation in MODIS (project) related activities. Efforts in this contract period have focused on radiative transfer modeling, evaluation of atmospheric correction methodologies, involvement in field studies, production and evaluation of new computer networking strategies, and objective analysis approaches.

MODIS INFRARED ALGORITHM DEVELOPMENT

A. Near Term Objectives

A.1. Continue algorithmic development efforts based on experimental match-up databases and radiative transfer models.

A.2. Continue interaction with the MODIS Instrument Team through meetings and electronic communications.

A.3 Continue evaluation of different approaches for global SST data assimilation and work on statistically based objective analysis approaches.

A.4 Continue evaluation of high-speed network interconnection technologies.

A.5 Continue evaluation of various *in situ* validation instruments for the MODIS IR bands.

A.6 Provide investigator and staff support for the preceding items.

B. Overview of Current Progress

B.1 January-June 1995

Activities during the past six months have continued on the previously initiated tasks. There have been specific continuing efforts in the areas of (a) radiative transfer modeling, (b) generation of model based retrieval algorithms, (c) continued work on IR calibration/validation as part of the MODIS Ocean Science Team cruise effort, and (e) work on test and evaluation of an experimental wide area network based on ATM technology. Previously initiated activities such as team related activities are ongoing. A special focus during this period was development of a validation approach for surface leaving infrared radiances.

B.1.1 Radiative Transfer Modeling

Simulations were done to study methods of splitting the various parameter spaces to improve retrieval equation accuracy. A tentative set of slowly varying parametric fits seems to improve algorithm performance. Discussions and initial work are underway to examine correction approaches based on fast-forward codes and those based on EOF decompositions of atmospheric profiles with exact forward calculated coefficients. It is currently unclear whether computer capability will permit implementation of the fast, forward RTE-based correction approach for routine atmospheric correction of MODIS retrievals.

Discussions were initiated by P. Minnett with A. Zavody concerning enhancements to the RTE radiative transfer simulation code. Minnett will modify the calculation sequence to retain multiple atmospheric levels in memory which should facilitate calculation and analyses. Zavody has agreed to furnish up-to-date spectral data to permit the simulation's use over the complete MODIS-IR band set.

B.1.2 Algorithm Development Efforts Based on Experimental Match-up Data bases

The main objective of our recent work is to explore the associations between atmospheric water vapor content and various AVHRR-derived quantities. Insight gained on the nature of these associations will allow us to better understand the performance of existing SST algorithms, as well as to improve the parameterization of various terms in such algorithms. The difference in brightness temperatures in AVHRR channels 4 and 5 is the quantity most often used as a proxy for atmospheric effects. Therefore, during this period we have dedicated considerable attention to exploring the association between this quantity and water vapor, including the effects of AVHRR viewing geometry, geographic location, and season. We are now validating a moving window temporal approach to retrieval equation generation. Testing over multi-year data sets demonstrates accuracy at the ≈0.5K RMS.

Simultaneously, studies were conducted to improve "clearing" of potentially contaminated retrievals from imagery and the comparison database. It was found that utilizing a rolling three-week mean as a basis for discriminating highly variant observations was quite effective in eliminating contaminated retrievals.

B.1.3 Wide Area Networking

Efforts to test experimental high speed network between the FORE and DIGITAL ATM switches at the University of Miami were successful in March. SVCs are being established routinely over these connections as appropriate. A network between heterogeneous machines, switches and adaptors (FORE, SGI and DEC) has been implemented and is in use in a production environment. This configuration routinely carries 20-40 Gigabytes of traffic per day. Tasks include disk-to-disk, disk-to-tape and tape-to-disk transfers. We have had one failure in this network since its installation.

B.1.4 *In Situ* Calibration/Validation of MODIS IR Radiances

Work was initiated during the previous six months to evaluate several new approaches to infrared radiance measurements cooperatively with Dr. William Smith of the University of Wisconsin. Specifically we participated in a joint study utilizing the NASA ER-2 (MAS and HIS), GOES-8, and two shipboard mounted instruments (AERI and Heimann KT-19). The study occurred in early January, 1995 in the western Gulf of Mexico between frontal passages. Dr. Peter Minnett (Brookhaven National Laboratory, now University of Miami) provided a portable surface meteorology package including long-wave downwelling (Eppley), and a fast response *in situ* temperature probe. Results demonstrate excellent surface radiance and temperature measurement and concomitant retrieval of SST. A paper reviewing the study was prepared (Smith, *et al*., 1995), submitted to *Bull. Amer. Meteor. Soc.*, and accepted in June 1995.

Pertinent results include:

- Intercomparison of satellite (GOES-8), aircraft (HIS) U2R/MAS and surface (AERI) and *in situ* temperatures (skimmer/PRT).

- Development of a straightforward model scheme for correction of sky radiance and surface emissivity effects on surface radiance.

- Absolute accuracy surface (skin) temperature observations with an RMS error of O.2^{o}C.

- Characterization of sea surface emissivity at large viewing angles and for variable wind speeds.

We have determined that the AERI will provide measurements of the accuracy and spectral characteristics needed for MODIS-IR algorithm development and validation. Therefore, procurement of two modified AERI instruments (Revercomb *et al*., 1993) for use in the marine environment as surface validation instruments was initiated. Resources available in this and the next contract year will be used for this effort. We expect delivery of the first instrument by mid 1996.

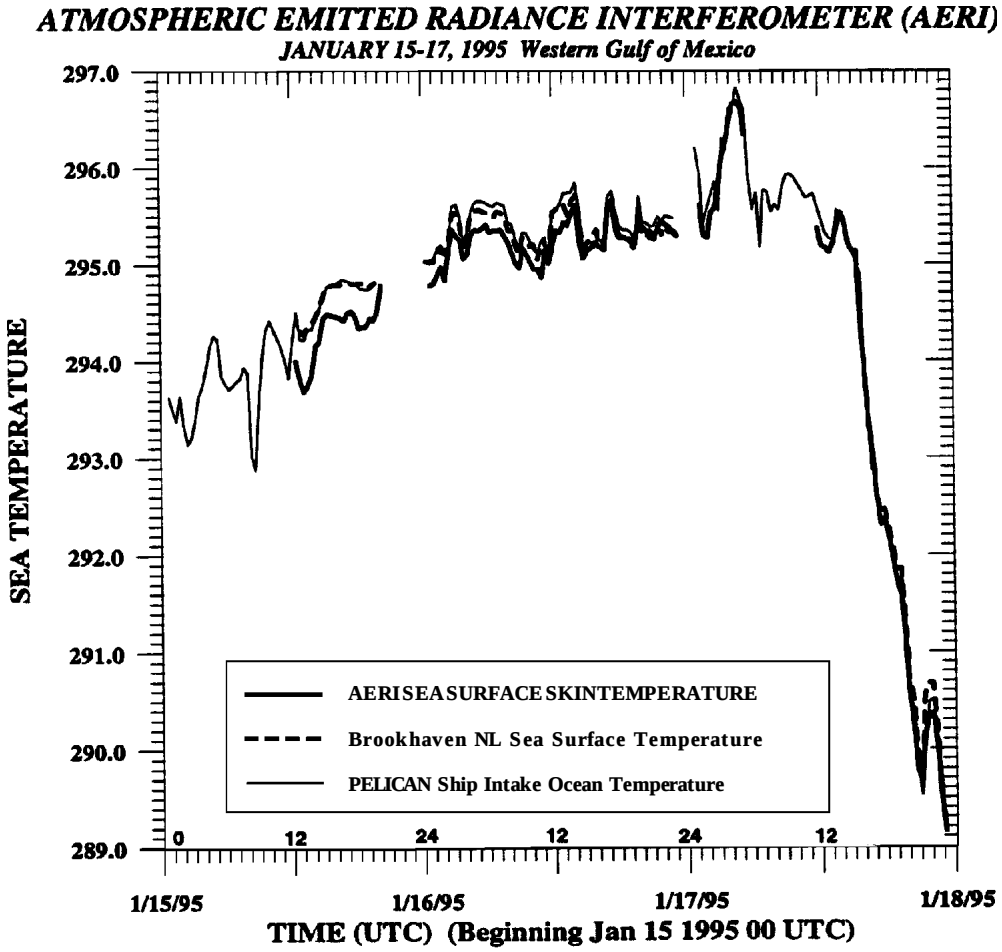

Figure 1: Comparison of remotely observed sea surface temperature with Pelican bulk ship intake ocean temperature and the Brookhaven National Laboratory surface skimmer. (Smith *et al*., 1995)

Figure 1 compares radiometric estimates of surface temperature derived from the AERI measurements (Smith *et al*., 1995) with ship intake and "skimmer" observations. This comparison is quite remarkable over most of the series. The departures on the 15th are thought to be due to diurnal warming during low and stress conditions.

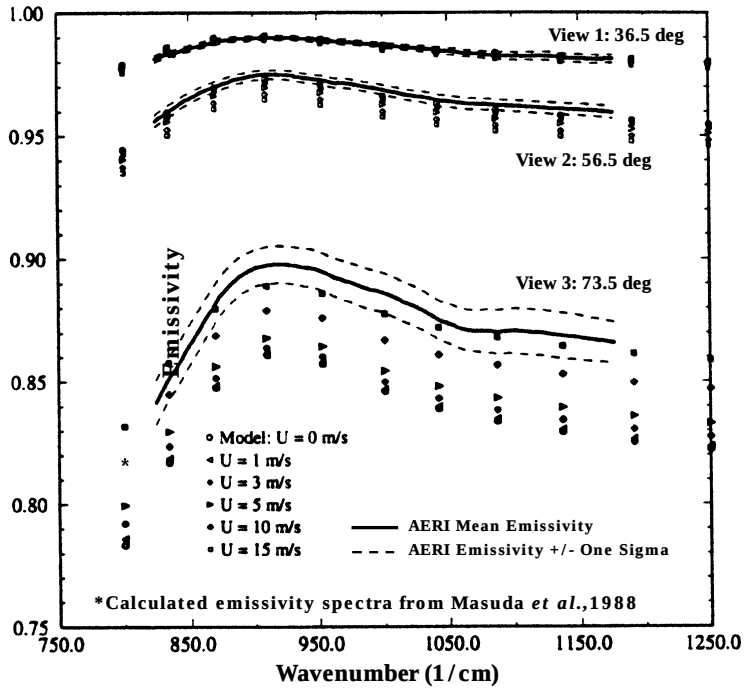

Figure 2: Comparison of AERI "observed" sea surface emissivity (solid) and calculations by Masuda *et al*., (1988), (symbols). The standard deviation of the mean for the entire day of 16 January is also shown (dashed lines). (Smith *et al*., 1995)

Figure 2 illustrates model calculated emissivities compared with derived AERI emissivities for a range of infrared wave numbers, viewing angles and wind speeds. The overall character of the agreement is good, but it is clear that the observed emissivities are biased slightly higher than the model results. This is an area of ongoing investigation and will be examined in more detail during future field studies.

C. Investigator Support

January	W. Baringer	A. Li	**April**	W. Baringer	A. Kroger
	O. Brown	S. Walsh		J. Brown	S. Walsh
February	W. Baringer	A. Li	**May**	J. Brown	S. Walsh
	O. Brown	S. Walsh		A. Kroger	
March	J. Brown	A. Kroger	**June**	J. Brown	A. Li
	A. Li	S. Walsh		V. Halliwell	P. Minnett
				D. Li	

D. Future Activities

D.1 Current:

D.1.1 Algorithms

a. Continue to develop and test algorithms on global retrievals
b. Evaluation of global data assimilation statistics for SST fields
c. Continue RT modeling using RAL code
d. ATBD updates (as needed)
e. Define and implement an extended ATM based network test bed
f. Evaluate and analyze results of calibration/validation experiment
g. Continued integration of new workstations into algorithm development environment

D.1.2 Investigator support

Continue current efforts

E. Problems

No new problems to report.

F. Publications

Smith, William L., R.O. Knuteson, H.E. Revercomb, W. Feltz, H.B. Howell, W.P. Menzel, N. Nalli, O.B. Brown, J. Brown, P. Minnett and W. McKeown. Observations of the Infrared Radiative Properties of the Ocean-Implications for the Measurement of Sea Surface Temperature via Satellite Remote Sensing. *Bull. Amer. Meteor. Soc.*, (accepted).

G. References:

Masuda, K., T. Takashima, Y. Takayama, 1988: Emissivity of Pure and Sea Waters for the Model Sea Surface in the Infrared Window Regions. Remote Sensing of the Environment, 24, 313-329.

Revercomb, H.E., F.A. Best, R.G. Dedecker, T.P. Dirkx, R.A. Herbsleb, R.O. Knuteson, J.F. Short, and W.L. Smith, 1993: Atmospheric Emitted Radiance Interferometer for ARM. Symposium on Global Change Studies. January 17-22, 1993, Preprint.